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(71) Applicant (for all designated States except US): **FOTO-NATION VISION LIMITED** [IE/IE]; Galway Business Park, Dangan, Galway City, Co. Galway (IE).

(72) Inventors; and

(75) Inventors/Applicants (for US only): **BIGIOI, Petronel** [RO/IE]; 57 Sceilg Ard, Headford Road, Galway, Co. Galway (IE). **CORCORAN, Peter** [IE/IE]; Cregg, Claregalway, Co. Galway (IE). **STEINBERG, Eran** [IE/US]; 137 Granville Way, San Francisco, CA 94127 (US).

(74) Agents: **SMITH, Andrew, V.** et al.; FotoNation IP Dept., 800 Airport Blvd., Suite 522, Burlingame, CA 94010 (US).

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(54) Title: IMAGE PROCESSING METHOD AND APPARATUS

(57) Abstract: An image processing technique includes acquiring a main image of a scene and determining one or more facial regions in the main image. The facial regions are analysed to determine if any of the facial regions includes a defect. A sequence of relatively low resolution images nominally of the same scene is also acquired. One or more sets of low resolution facial regions in the sequence of low resolution images are determined and analysed for defects. Defect free facial regions of a set are combined to provide a high quality defect free facial region. At least a portion of any defective facial regions of the main image are corrected with image information from a corresponding high quality defect free facial region.



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## IMAGE PROCESSING METHOD AND APPARATUS

### CROSS-RELATED PATENT APPLICATIONS

This application is related to United States Patent Application No.11/752,925, filed May 24,  
5 2007, and is hereby incorporated by reference.

### BACKGROUND

The present invention relates to an image processing method and apparatus. One of the most  
common reasons for an acquired digital photograph to be discarded or spoiled is because one or  
10 more of the facial regions in the photograph suffer from photographic defects other than red-eye  
defects, even though red eye defects can be common in cameras not operating with the  
advantages of the techniques described, e.g., at US patent 6,407,777, and at US published  
applications nos. 2005/0140801, 2005/0041121, 2006/0093212, and 2006/0204054, which are  
assigned to the same assignee and hereby incorporated by reference. Common examples occur  
15 when people move or shake their head; when someone closes their eyes or blinks or someone  
yawns. Where there are several faces in a photograph, it is sufficient for one face to be  
“defective” for the whole shot to be spoiled. Although digital cameras allow users to quickly  
shoot several pictures of the same scene. Typically, such cameras do not provide warnings of  
facial errors, nor provide a way to correct for such errors without repeating the composition  
20 stages (i.e. getting everyone together again in a group) of taking the photograph and re-shooting  
the scene. This type of problem is particularly difficult with children who are often photographed  
in unusual spontaneous poses which cannot be duplicated. When such a shot is spoiled because  
the child moved their head at the moment of acquisition, it is very disappointing for the  
photographer.

25 US patent no. 6,301,440, which is incorporated by reference, discloses an image acquisition  
device wherein the instant of exposure is controlled by image content. When a trigger is  
activated, the image proposed by the user is analysed and imaging parameters are altered to  
obtain optimum image quality before the device proceeds to take the image. For example, the  
30 device could postpone acquisition of the image until every person in the image is smiling.

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### SUMMARY OF THE INVENTION

An image processing method is provided including acquiring a main image of a scene. One or more facial regions are determined in the main image. The one or more main image facial regions are analyzed for defects and one or more are determined to be defective. A sequence of relatively low resolution images nominally of the scene are acquired. One or more sets of low resolution facial regions in the sequence are analyzed to determine one or more that correspond to a defective main image facial region. At least a portion of the defective main image facial region is corrected with image information from one or more corresponding low resolution facial regions not including a same defect as said portion of said defective main image facial region.

The sequence of low resolution images may be specifically acquired for a time period not including a time for acquiring the main image. The method may also include combining defect-free low resolution facial regions into a combined image, and correcting at least the portion of the defective main image facial region with image information from the combined image.

Another image processing method is provided that including acquiring a main image of a scene. One or more facial regions in the main image are determined, and analyzed to determine if any are defective. A sequence of relatively low resolution images is acquired nominally of the scene for a time period not including a time for acquiring the main image. One or more sets of low resolution facial regions are determined in the sequence of low resolution images. The sets of facial regions are analyzed to determine if any facial regions of a set corresponding to a defective facial region of the main image include a defect. Defect free facial regions of the corresponding set are combined to provide a high quality defect free facial region. At least a portion of any defective facial regions of said main image are corrected with image information from a corresponding high quality defect free facial region.

The time period may include one or more of a time period preceding or a time period following the time for acquiring the main image. The correcting may include applying a model including multiple vertices defining a periphery of a facial region to each high quality defect-free facial region and a corresponding defective facial region. Pixels may be mapped of the high quality

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defect-free facial region to the defective facial region according to the correspondence of vertices for the respective regions. The model may include an Active Appearance Model (AAM).

5 The main image may be acquired at an exposure level different to the exposure level of the low resolution images. The correcting may include mapping luminance levels of the high quality defect free facial region to luminance levels of the defective facial region.

Sets of low resolution facial regions from the sequence of low resolution images may be stored in an image header file of the main image.

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The method may include displaying the main image and/or corrected image, and selected actions may be user-initiated.

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The analyzing of the sets may include, prior to the combining in the second method, removing facial regions including faces exceeding an average size of faces in a set of facial regions by a threshold amount from said set of facial regions, and/or removing facial regions including faces with an orientation outside an average orientation of faces in a set of facial regions by a threshold amount from said set of facial regions.

20

The analyzing of sets may include the following:

applying an Active Appearance Model (AAM) to each face of a set of facial regions;

analyzing AAM parameters for each face of the set of facial regions to provide an indication of facial expression; and

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prior to the combining in the second method, removing faces having a defective expression from the set of facial regions.

The analyzing of sets may include the following:

applying an Active Appearance Model (AAM) to each face of a set of facial regions;

analysing AAM parameters for each face of the set of facial regions to provide an

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indication of facial orientation; and

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prior to said combining in the second method, removing faces having an undesirable orientation from said set of facial regions.

The analyzing of facial regions may include applying an Active Appearance Model (AAM) to  
5 each facial region, and analyzing AAM parameters for each facial region to provide an indication  
of facial expression, and/or analyzing each facial region for contrast, sharpness, texture,  
luminance levels or skin color or combinations thereof, and/or analyzing each facial region to  
determine if an eye of the facial region is closed, if a mouth of the facial region is open and/or if  
a mouth of the facial region is smiling.

10 The method may be such that the correcting, and the combining in the second method, only  
occur when the set of facial regions exceeds a given number. The method may also include  
resizing and aligning faces of the set of facial regions, and the aligning may be performed  
according to cardinal points of faces of the set of facial regions.

15 The correcting may include blending and/or infilling a corrected region of the main image with  
the remainder of the main image.

#### BRIEF DESCRIPTION OF THE DRAWINGS

20 Embodiments will now be described, by way of example, with reference to the accompanying  
drawings, in which:

Figure 1 is a block diagram of an image processing apparatus operating in accordance with an  
embodiment of the present invention;

25 Figure 2 is a flow diagram of an image processing method according to a preferred embodiment  
of the present invention; and

Figures 3 and 4 show exemplary sets of images to which an active appearance model has been  
30 applied.

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#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Certain embodiments can be implemented with a digital camera which incorporates (i) a face tracker operative on a preview image stream; (ii) a super-resolution processing module configured to create a higher resolution image from a composite of several low-resolution  
5 images; and (iii) a facial region quality analysis module for determining the quality of facial regions.

Preferably, super-resolution is applied to preview facial regions extracted during face tracking.

10 The embodiments enable the correction of errors or flaws in the facial regions of an acquired image within a digital camera using preview image data and employing super-resolution techniques.

Figure 1 is a block diagram of an image acquisition device 20, which in the present embodiment  
15 is a portable digital camera, operating in accordance with certain embodiments. It will be appreciated that many of the processes implemented in the digital camera are implemented in or controlled by software operating on a microprocessor, central processing unit, controller, digital signal processor and/or an application specific integrated circuit, collectively depicted as processor 120. All user interface and control of peripheral components such as buttons and  
20 display is controlled by a microcontroller 122.

In operation, the processor 120, in response to a user input at 122, such as half pressing a shutter button (pre-capture mode 32), initiates and controls the digital photographic process. Ambient light exposure is determined using a light sensor 40 in order to automatically determine if a flash  
25 is to be used. The distance to the subject is determined using a focusing mechanism 50 which also focuses the image on an image capture device 60. If a flash is to be used, processor 120 causes a flash device 70 to generate a photographic flash in substantial coincidence with the recording of the image by the image capture device 60 upon full depression of the shutter button. The image capture device 60 digitally records the image in colour. The image capture device is  
30 known to those familiar with the art and may include a CCD (charge coupled device) or CMOS to facilitate digital recording. The flash may be selectively generated either in response to the

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light sensor 40 or a manual input 72 from the user of the camera. The high resolution image recorded by image capture device 60 is stored in an image store 80 which may comprise computer memory such a dynamic random access memory or a non-volatile memory. The camera is equipped with a display 100, such as an LCD, both for displaying preview images and displaying a user interface for camera control software.

In the case of preview images which are generated in the pre-capture mode 32 with the shutter button half-pressed, the display 100 can assist the user in composing the image, as well as being used to determine focusing and exposure. Temporary storage 82 is used to store one or plurality of the stream of preview images and can be part of the image store 80 or a separate component. The preview image is usually generated by the image capture device 60. For speed and memory efficiency reasons, preview images usually have a lower pixel resolution than the main image taken when the shutter button is fully depressed, and are generated by sub-sampling a raw captured image using software 124 which can be part of the general processor 120 or dedicated hardware or combination thereof.

In the present embodiment, a face detection and tracking module 130 such as described in US Application No. 11/464,083, filed August 11, 2006, which is hereby incorporated by reference, is operably connected to the sub-sampler 124 to control the sub-sampled resolution of the preview images in accordance with the requirements of the face detection and tracking module. Preview images stored in temporary storage 82 are available to the module 130 which records the locations of faces tracked and detected in the preview image stream. In one embodiment, the module 130 is operably connected to the display 100 so that boundaries of detected and tracked face regions can be superimposed on the display around the faces during preview.

In the embodiment of Figure 1, the face tracking module 130 is arranged to extract and store tracked facial regions at relatively low resolution in a memory buffer such as memory 82 and possibly for storage as meta-data in an acquired image header stored in memory 80. Where multiple face regions are tracked, a buffer is established for each tracked face region. These buffers are of finite size (10-20 extracted face regions in a preferred embodiment) and generally operate on a first-in-first-out (FIFO) basis.

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According to the preferred embodiment, the device 20 further comprises an image correction module 90. Where the module 90 is arranged for off-line correction of acquired images in an external processing device 10, such as a desktop computer, a colour printer or a photo kiosk, face regions detected and/or tracked in preview images are preferably stored as meta-data within the image header. However, where the module 90 is implemented within the camera 20, it can have direct access to the buffer 82 where preview images and/or face region information is stored.

In this embodiment, the module 90 receives the captured high resolution digital image from the store 80 and analyzes it to detect defects. The analysis is performed as described in the embodiments to follow. If defects are found, the module can modify the image to remove the defect. The modified image may be either displayed on image display 100, saved on a persistent storage 112 which can be internal or a removable storage such as CF card, SD card or the like, or downloaded to another device via image output means 110 which can be tethered or wireless. The module 90 can be brought into operation either automatically each time an image is captured, or upon user demand via input 30. Although illustrated as a separate item, where the module 90 is part of the camera, it may be implemented by suitable software on the processor 120.

The main components of the image correction module include a quality module 140 which is arranged to analyse face regions from either low or high resolution images to determine if these include face defects. A super-resolution module 160 is arranged to combine multiple low-resolution face regions of the same subject generally with the same pose and a desirable facial expression to provide a high quality face region for use in the correction process. In the present embodiment, an active appearance model (AAM) module 150 produces AAM parameters for face regions again from either low or high resolution images.

AAM modules are well known and a suitable module for the present embodiment is disclosed in "Fast and Reliable Active Appearance Model Search for 3-D Face Tracking", F Dornaika and J Ahlberg, IEEE Transactions on Systems, Man, and Cybernetics-Part B: Cybernetics, Vol. 34, No. 4, pg 1838-1853, August 2004, although other models based on the original paper by TF



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Cootes et al "Active Appearance Models" Proc. European Conf. Computer Vision, 1998, pp 484-498 could also be employed.

The AAM module 150 can preferably cooperate with the quality module 140 to provide pose and/or expression indicators to allow for selection of images in the analysis and optionally in the correction process described below. Also, the AAM module 150 can preferably cooperate with the super-resolution module 160 to provide pose indicators to allow for selection of images in the correction process, again described in more detail below.

Referring now to Figure 2, which illustrates an exemplary processing flow for certain embodiments, when a main image is acquired, step 230, the location and size of any detected/tracked face region(s) in the main acquired image (high resolution) will be known by the module 90 from the module 130. Face detection can either be applied directly on the acquired image and/or information for face regions previously detected and/or tracked in the preview stream can be used for face detection in the main image (indicated by the dashed line extending from step 220). At step 250, the facial region quality analysis module 140 extracts and analyzes face regions tracked/detected at step 240 in the main image to determine the quality of the acquired face regions. For example, the module 140 can apply a preliminary analysis to measure the overall contrast, sharpness and/or texture of detected face region(s). This can indicate if the entire face region was blurred due to motion of the subject at the instant of acquisition. If a facial region is not sufficiently well defined then it is marked as a blur defect. In additional or alternatively, another stage of analysis can focus on the eye region of the face(s) to determine if one, or both eyes were fully or partially closed at the instant of acquisition and the face region is categorized accordingly. As mentioned previously, if AAM analysis is performed on the image, then the AAM parameters can be used to indicate whether a subject's eyes are open or not. It should be noted that in the above analyses, the module 90 detects blink or blur due to localized movement of the subject as opposed to global image blur.

Another or alternative stage of analysis focuses on the mouth region and determines if the mouth is opened in a yawn or indeed not smiling; again the face region is categorized accordingly. As

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mentioned previously, if AAM analysis is performed on the image, then the AAM parameters can be used to indicate the state of a subject's mouth.

Other exemplary tests might include luminance levels, skin colour and texture histograms, abrupt  
5 facial expressions (smiling, frowning) which may cause significant variations in facial features (mouth shape, furrows in brow). Specialized tests can be implemented as additional or alternative image analysis filters, for example, a Hough transform filter could be used to detect parallel lines in a face region above the eyes indicating a "furrowed brow". Other image analysis techniques such as those known in the art and as disclosed in US 6,301,440 can also be  
10 employed to categorise the face region(s) of the main image.

After this analysis, it is decided (for each face region) if any of these defects occurred, step 260, and the camera or external processing device user can be offered the option of repairing the defect based on the buffered (low resolution) face region data, step 265.

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When the repair option is actuated by the user, each of the low-resolution face regions is first analyzed by the face region quality analyzer, step 270. As this analysis is operative on lower resolution images acquired and stored at steps 200/210, the analysis may vary from the analysis of face regions in the main acquired image at step 250. Nevertheless the analysis steps are  
20 similar in that each low-resolution face region is analyzed to determine if it suffers from image defects in which case it should not be selected at step 280 to reconstruct the defective face region(s) in the main image. After this analysis and selection, if there are not enough "good" face regions corresponding to a defective face region available from the stream of low-resolution images, an indication is passed to the user that image repair is not viable. Where there are  
25 enough "good" face regions, these are passed on for resizing and alignment, step 285.

This step re-sizes each face region and performs some local alignment of cardinal face points to correct for variations in pose and to ensure that each of the low-resolution face regions overlap one another as uniformly as is practical for later processing.

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It should also be noted that as these image regions were captured in sequence and over a relatively short duration, it is expected that they are of approximately the same size and orientation. Thus, image alignment can be achieved using cardinal face points, in particular those relating to the eyes, mouth, lower face (chin region) which is normally delineated by a distinct boundary edge, and the upper face which is normally delineated by a distinctive hairline boundary. Some slight scaling and morphing of extracted face regions may be used to achieve reasonable alignment, however a very precise alignment of these images is not desirable as it would undermine the super-resolution techniques which enable a higher resolution image to be determined from several low-resolution images.

It should be noted that the low-resolution images captured and stored at steps 200/210 can be captured either from a time period before capturing the main image or from a period following capture of the main image (indicated by the dashed line extending from step 230). For example, it may be possible to capture suitable defect free low resolution images in a period immediately after a subject has stopped moving/blinking etc following capture of the main image.

This set of selected defect free face regions is next passed to a super-resolution module 160 which combines them using known super-resolution methods to yield a high resolution face region which is compatible with a corresponding region of the main acquired image.

Now the system has available to it, a high quality defect-free combination face region and a high resolution main image with a generally corresponding defective face region.

If this has not already been performed for quality analysis, the defective face region(s) as well as the corresponding high quality defect-free face region are subjected to AAM analysis, step 300. Referring now to Figure 3(a) to (d), which illustrates some images including face regions which have been processed by the AAM module 150. In this case, the model represented by the wire frame superimposed on the face is tuned for a generally forward facing and generally upright face, although separate models can be deployed for use with inclined faces or faces in profile.

Once the model has been applied, it returns a set of coordinates for the vertices of the wire frame; as well as texture parameters for each of the triangular elements defined by adjacent

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vertices. The relative coordinates of the vertices as well as the texture parameters can in turn provide indicators linked to the expression and inclination of the face which can be used in quality analysis as mentioned above.

5 It will therefore be seen that the AAM module 150 can also be used in the facial region analysis steps 250/270 to provide an indicator of whether a mouth or eyes are open i.e. smiling and not blinking; and also to help determine in steps 285/290 implemented by the super-resolution module 160 whether facial regions are similarly aligned or inclined for selection before super-resolution.

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So, using Figure 3(a) as an example of a facial region produced by super-resolution of low resolution images, it is observed that the set of vertices comprising the periphery of the AAM model define a region which can be mapped on to corresponding set of peripheral vertices of Figures 3(b) to Figure 3(d) where these images have been classified and confirmed by the user as defective facial regions and candidates for correction.

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In relation to Figure 4, the model parameters for Figures 4(a) or 4(b) which might represent super-resolved defect free face regions could indicate that the left-right orientation of these face regions would not make them suitable candidates for correcting the face region of Figure 4(c).

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Similarly, the face region of Figure 4(f) could be a more suitable candidate than the face region of Figure 4(e) for correcting the face region of Figure 4(d).

25

In any case, if the super-resolved face region is deemed to be compatible with the defective face region, information from the super-resolved face region can be pasted onto the main image by any suitable technique to correct the face region of the main image, step 320. The corrected image can be viewed and depending on the nature of the mapping, it can be adjusted by the user, before being finally accepted or rejected, step 330. So for example, where dithering around the periphery of the corrected face region is used as part of the correction process, step 320, the degree of dithering can be adjusted. Similarly, luminance levels or texture parameters in the corrected regions can be manually adjusted by the user, or indeed any parameter of the corrected

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region and the mapping process can be manually adjusted prior to final approval or rejection by the user.

While AAM provides one approach to determine the outside boundary of a facial region, other  
5 well-known image processing techniques such as edge detection, region growing and skin color  
analysis may be used in addition or as alternatives to AAM. However, these may not have the  
advantage of also being useful in analysing a face region for defects and/or for pose information.  
Other techniques which can prove useful include applying foreground/background separation to  
either the low-resolution images or the main image prior to running face detection to reduce  
10 overall processing time by only analysing foreground regions and particularly foreground skin  
segments. Local colour segmentation applied across the boundary of a foreground/background  
contour can assist in further refining the boundary of a facial region.

Once the user is satisfied with the placement of the reconstructed face region they may choose to  
15 merge it with the main image; alternatively, if they are not happy they can cancel the  
reconstruction process. These actions are typically selected through buttons on the camera user  
interface where the correction module is implemented on the acquisition device 20.

As practical examples let us consider an example of the system used to correct an eye defect. An  
20 example may be used of a defect where one eye is shut in the main image frame due to the  
subject "blinking" during the acquisition. Immediately after the main image acquisition the user  
is prompted to determine if they wish to correct this defect. If they confirm this, then the camera  
begins by analyzing a set of face regions stored from preview images acquired immediately prior  
to the main image acquisition. It is assumed that a set of, say, 20 images was saved from the one  
25 second period immediately prior to image acquisition. As the defect was a blinking eye, the  
initial testing determines that the last, say, 10 of these preview images are not useful. However  
the previous 10 images are determined to be suitable. Additional testing of these images might  
include the determination of facial pose, eliminating images where the facial pose varies more  
than 5% from the averaged pose across all previews; a determination of the size of the facial  
30 region, eliminating images where the averaged size varies more than 25% from the averaged size

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across all images. The reason the threshold is higher for the latter test is that it is easier to rescale face regions than to correct for pose variations.

In variations of the above described embodiment, the regions that are combined may include  
5 portions of the background region surrounding the main face region. This is particularly  
important where the defect to be corrected in the main acquired image is due to face motion  
during image exposure. This will lead to a face region with a poorly defined outer boundary in  
the main image and the super-resolution image which is superimposed upon it typically  
incorporates portions of the background for properly correcting this face motion defect. A  
10 determination of whether to include background regions for face reconstruction can be made by  
the user, or may be determined automatically after a defect analysis is performed on the main  
acquired image. In the latter case, where the defect comprises blurring due to face motion, then  
background regions will normally be included in the super-resolution reconstruction process. In  
an alternative embodiment, a reconstructed background can be created using either (i) region  
15 infilling techniques for a background region of relatively homogeneous colour and texture  
characteristics, or (ii) directly from the preview image stream using image alignment and super-  
resolution techniques. In the latter case the reconstructed background is merged into a gap in the  
main image background created by the separation of foreground from background; the  
reconstructed face region is next merged into the separated foreground region, specifically into  
20 the facial region of the foreground and finally the foreground is re-integrated with the enhanced  
background region.

After applying super-resolution methods to create a higher resolution face region from multiple  
low-resolution preview images, some additional scaling and alignment operations are normally  
25 involved. Furthermore, some blending, infilling and morphological operations may be used in  
order to ensure a smooth transition between the newly constructed super-resolution face region  
and the background of the main acquired image. This is particularly the case where the defect to  
be corrected is motion of the face during image exposure. In the case of motion defects it may  
also be desirable to reconstruct portions of the image background prior to integration of the  
30 reconstructed face region into the main image.

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It is also be desirable to match the overall luminance levels of the new face region with that of the old face region, and this is best achieved through a matching of the skin colour between the old region and the newly constructed one. Preview images are acquired under fixed camera settings and can be over/under exposed. This may not be fully compensated for during the super-resolution process and may involve additional image processing operations.

While the above described embodiments have been directed to replacing face regions within an image, it will be seen that AAM can be used to model any type of feature of an image. So in certain embodiments, the patches to be used for super-resolution reconstruction may be sub-regions within a face region. For example, it may be desired to reconstruct only a segment of the face regions, such as an eye or mouth region, rather than the entire face region. In such cases, a determination of the precise boundary of the sub-region is of less importance as the sub-region will be merged into a surrounding region of substantially similar colour and texture (i.e. skin colour and texture). Thus, it is sufficient to center the eye regions to be combined or to align the corners of the mouth regions and to rely on blending the surrounding skin coloured areas into the main image.

In one or more of the above embodiments, separate face regions may be individually tracked (see also US application 11/464,083, which is hereby incorporated by reference). Regions may be tracked from frame-to-frame. Preview or post-view face regions can be extracted, analyzed and aligned with each other and with the face region in the main or final acquired image. In addition, in techniques according to certain embodiments, faces may be tracked between frames in order to find and associate smaller details between previews or post-views on the face. For example, a left eye from Joe's face in preview N may be associated with a left eye from Joe's face in preview N+1. These may be used together to form one or more enhanced quality images of Joe's eye. This is advantageous because small features (an eye, a mouth, a nose, an eye component such as an eye lid or eye brow, or a pupil or iris, or an ear, chin, beard, mustache, forehead, hairstyle, etc.. are not as easily traceable between frames as larger features (and their absolute or relative positional shifts between frames tend to be more substantial relative to their size.

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The present invention is not limited to the embodiments described above herein, which may be amended or modified without departing from the scope of the present invention as set forth in the appended claims, and structural and functional equivalents thereof.

5 In methods that may be performed according to preferred embodiments herein and that may have been described above and/or claimed below, the operations have been described in selected typographical sequences. However, the sequences have been selected and so ordered for typographical convenience and are not intended to imply any particular order for performing the operations.

10

In addition, all references cited above herein, in addition to the background and summary of the invention sections themselves, are hereby incorporated by reference into the detailed description of the preferred embodiments as disclosing alternative embodiments and components. The following are also incorporated by reference for this purpose: US patent applications nos.

15 60/829,127, 60/804,546, 60/821,165 11/554,539, 11/464,083, 11/027,001, 10/842,244, 11/024,046, 11/233,513, 11/460,218, 11/573,713, 11/319,766, 11/464,083, 11/744,020 and 11/460,218, and U.S. published application no. 2006/0285754.



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Claims:

1. An image processing method comprising:

a) acquiring a main image of a scene;

b) determining one or more facial regions in said main image;

c) analysing said one or more facial regions to determine if any one of said facial regions includes a defect;

d) acquiring a sequence of relatively low resolution images nominally of said scene for a time period not including a time for acquiring said main image;

e) determining one or more sets of low resolution facial regions in said sequence of low resolution images;

f) analysing said sets of facial regions to determine if any facial regions of a set corresponding to a defective facial region of said main image include a defect;

g) combining defect free facial regions of said corresponding set to provide a high quality defect free facial region; and

h) correcting at least a portion of any defective facial regions of said main image with image information from a corresponding high quality defect free facial region.

2. A method according to claim 1 wherein said time period includes one or more of a time period preceding or a time period following said time for acquiring said main image.

3. A method according to claim 1 wherein said correcting step comprises:

applying a model comprising a plurality of vertices defining a periphery of a facial region to each high quality defect free facial region and a corresponding defective facial region; and

mapping pixels of said high quality defect free facial region to said defective facial region according to the correspondence of vertices for said respective regions.

4. A method according to claim 3 wherein said model comprises an Active Appearance Model (AAM).

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5. A method according to claim 1 wherein said main image is acquired at an exposure level different to the exposure level of said low resolution images and wherein said correcting comprises mapping luminance levels of said high quality defect free facial region to luminance levels of said defective facial region.

5

6. A method according to claim 1 comprising storing sets of low resolution facial regions from said sequence of low resolution images in an image header file of said main image.

7. A method according to claim 1, wherein said step f) of analysing further comprises: prior to said combining, removing facial regions including faces exceeding an average size of faces in a set of facial regions by a threshold amount from said set of facial regions.

10

8. A method according to claim 1, wherein said step f) of analysing further comprises: prior to said combining, removing facial regions including faces with an orientation outside an average orientation of faces in a set of facial regions by a threshold amount from said set of facial regions.

15

9. A method according to claim 1 comprising displaying said main image; and responsive to user interaction, performing steps c) and steps f) to h).

20

10. A method according to claim 1 wherein step e) is performed at a time preceding performing step a).

11. A method according to claim 1 comprising: displaying said corrected image; and responsive to user interaction, saving said corrected image.

25

12. A method according to claim 1 wherein said step f) of analysing comprises:  
applying an Active Appearance Model (AAM) to each face of a set of facial regions;  
analysing AAM parameters for each face of the set of facial regions to provide an indication of facial expression; and

30

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prior to said combining, removing faces having a defective expression from said set of facial regions.

13. A method according to claim 1 wherein said step f) of analysing comprises:  
5 applying an Active Appearance Model (AAM) to each face of a set of facial regions;  
analysing AAM parameters for each face of the set of facial regions to provide an indication of facial orientation; and  
prior to said combining, removing faces having an undesirable orientation from said set of facial regions.

10 14. A method according to claim 1 wherein said step c) of analysing comprises:  
applying an Active Appearance Model (AAM) to each facial region; and  
analysing AAM parameters for each facial region to provide an indication of facial expression.

15 15. A method according to claim 1 wherein said step c) of analysing comprises:  
analysing each facial region for one or more of: contrast, sharpness, texture, luminance levels or skin color.

20 16. A method according to claim 1 wherein said step c) of analysing comprises:  
analysing each facial region to determine if any eyes of said facial region are closed.

17. A method according to claim 1 wherein said step c) of analysing comprises:  
analysing each facial region to determine if any mouth of said facial region is open.

25 18. A method according to claim 1 wherein said step c) of analysing comprises:  
analysing each facial region to determine if any mouth of said facial region is smiling.

19. A method according to claim 1 wherein steps g) and h) are performed only when said set  
30 of facial regions exceeds a given number.

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20. A method according to claim 1 comprising: prior to said combining, resizing and aligning faces of said set of facial regions.

21. A method according to claim 20, wherein said aligning is performed according to  
5 cardinal points of faces of said set of facial regions.

22. A method according to claim 1 wherein said correcting further comprises one or more of: blending; or infilling a corrected region of said main image with the remainder of said main  
10 image.

23. A method according to claim 1 comprising: displaying said corrected image; and responsive to user interaction, adjusting the correction of said corrected image.

24. An image processing method comprising:  
15 a) acquiring a main image of a scene;  
b) determining one or more facial regions in said main image;  
c) analysing said one or more main image facial regions for defects and determining that one or more are defective;  
d) acquiring a sequence of relatively low resolution images nominally of said scene;  
20 e) determining one or more sets of low resolution facial regions in said sequence of low resolution images;  
f) analysing said one or more sets of low resolution facial regions to determine one or more that correspond to a defective main image facial region;  
g) correcting at least a portion of a defective main image facial region with image  
25 information from one or more corresponding low resolution facial regions not including a same defect as said portion of said defective main image facial region.

25. A method according to claim 24 wherein said correcting comprises:  
applying a model comprising a plurality of vertices defining a periphery of a facial region  
30 to one or more low resolution facial regions not including said same defect and a corresponding defective main image facial region; and

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mapping pixels of said one or more low resolution facial regions to said corresponding defective main image facial region according to the correspondence of vertices for respective regions.

5 26. A method according to claim 25 wherein said model comprises an Active Appearance Model (AAM).

10 27. A method according to claim 24 wherein said main image is acquired at an exposure level different than the exposure level of said low resolution images and wherein said correcting comprises mapping luminance levels of one or more low resolution facial regions not have said same defect to luminance levels of said defective main image facial region.

15 28. A method according to claim 24 comprising storing sets of low resolution facial regions from said sequence of low resolution images in an image header file of said main image.

29. A method according to claim 24, wherein said analysing said one or more sets further comprises removing facial regions including faces exceeding an average size of faces in at least one set of facial regions by a threshold amount from said at least one set of facial regions.

20 30. A method according to claim 24, wherein said analysing said one or more sets further comprises removing facial regions including faces with an orientation outside an average orientation of faces in a set of facial regions by a threshold amount from said set of facial regions.

25 31. A method according to claim 24, further comprising displaying said main image; and responsive to user interaction, selectively performing said analyzing said one or more facial regions, said analyzing said one of more sets or said correcting, or combinations thereof.

30 32. A method according to claim 24, further comprising displaying a corrected image based on said correcting, and responsive to user interaction, saving said corrected image.

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33. A method according to claim 24, wherein said analysing said one or more sets comprises:  
applying an Active Appearance Model (AAM) to each face of a set of facial regions;  
analysing AAM parameters for each face of the set of facial regions to provide an  
indication of facial expression; and

5 prior to said combining, removing faces having a defective expression from said set of  
facial regions.

34. A method according to claim 24, wherein said analysing said one or more sets comprises:  
applying an Active Appearance Model (AAM) to each face of a set of facial regions;  
10 analysing AAM parameters for each face of the set of facial regions to provide an  
indication of facial orientation; and

prior to said combining, removing faces having an undesirable orientation from said set  
of facial regions.

15 35. A method according to claim 24 wherein said analysing one or more facial regions  
comprises:

applying an Active Appearance Model (AAM) to each facial region; and  
analysing AAM parameters for each facial region to provide an indication of facial  
expression.

20 36. A method according to claim 24, wherein said analysing one or more facial regions  
comprises analysing at least one facial region to determine if an eye of said facial region is  
closed.

25 37. A method according to claim 24, wherein said analysing one or more facial regions  
comprises analysing at least one facial region to determine if a mouth of said facial region is  
open.

30 38. A method according to claim 24, wherein said analysing one or more facial regions  
comprises analysing at least one facial region to determine if a mouth of said facial region is  
frowning.

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39. A method according to claim 24 further comprising displaying a corrected image based on said correcting and responsive to user interaction, adjusting the correcting of said corrected image.

5

40. A method according to claim 24, wherein said sequence of low resolution images is acquired for a time period not including a time for acquiring said main image.

41. A method according to claim 24, further comprising combining defect-free low resolution facial regions into a combined image, and correcting at least said portion of said defective main image facial region with image information from the combined image.

10

42. An image processing apparatus comprising:

a) means for acquiring a main image of a scene;

15

b) means for determining one or more facial regions in said main image;

c) analysing said one or more facial regions to determine if any one of said facial regions includes a defect;

d) means for acquiring a sequence of relatively low resolution images nominally of said scene for a time period not including a time for acquiring said main image;

20

e) means for determining one or more sets of low resolution facial regions in said sequence of low resolution images;

f) means for analysing said sets of facial regions to determine if any facial regions of a set corresponding to a defective facial region of said main image include a defect;

25

g) means for combining defect free facial regions of said corresponding set to provide a high quality defect free facial region; and

h) means for correcting at least a portion of any defective facial regions of said main image with image information from a corresponding high quality defect free facial region.

43. An image processing apparatus according to claim 42 comprising a digital image acquisition device or general purpose computer or both.

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44. An apparatus for providing images with enhanced facial regions in digital images, including a processor and one or more processor-readable media for programming the processor to control the apparatus to perform an image processing method that comprises:

a) acquiring a main image of a scene;

5 b) determining one or more facial regions in said main image;

c) analysing said one or more main image facial regions for defects and determining that one or more are defective;

d) acquiring a sequence of relatively low resolution images nominally of said scene;

10 e) determining one or more sets of low resolution facial regions in said sequence of low resolution images;

f) analysing said one or more sets of low resolution facial regions to determine one or more that correspond to a defective main image facial region; and

15 g) correcting at least a portion of a defective main image facial region with image information from one or more corresponding low resolution facial regions not including a same defect as said portion of said defective main image facial region.

45. An apparatus according to claim 44, wherein said correcting comprises:

20 applying a model comprising a plurality of vertices defining a periphery of a facial region to one or more low resolution facial regions not including said same defect and a corresponding defective main image facial region; and

mapping pixels of said one or more low resolution facial regions to said corresponding defective main image facial region according to the correspondence of vertices for respective regions.

25 46. An apparatus according to claim 45 wherein said model comprises an Active Appearance Model (AAM).

30 47. An apparatus according to claim 44 wherein said main image is acquired at an exposure level different than the exposure level of said low resolution images and wherein said correcting comprises mapping luminance levels of one or more low resolution facial regions not have said same defect to luminance levels of said defective main image facial region.



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48. An apparatus according to claim 44 wherein the method further comprises storing sets of low resolution facial regions from said sequence of low resolution images in an image header file of said main image.

5

49. An apparatus according to claim 44, wherein said analysing said one or more sets further comprises removing facial regions including faces exceeding an average size of faces in at least one set of facial regions by a threshold amount from said at least one set of facial regions.

10 50. An apparatus according to claim 44, wherein said analysing said one or more sets further comprises removing facial regions including faces with an orientation outside an average orientation of faces in a set of facial regions by a threshold amount from said set of facial regions.

15 51. An apparatus according to claim 44, wherein the method further comprises displaying said main image; and responsive to user interaction, selectively performing said analyzing said one or more facial regions, said analyzing said one of more sets or said correcting, or combinations thereof.

20 52. An apparatus according to claim 44, wherein the method further comprises displaying a corrected image based on said correcting, and responsive to user interaction, saving said corrected image.

25 53. An apparatus according to claim 44, wherein said analysing said one or more sets comprises:

applying an Active Appearance Model (AAM) to each face of a set of facial regions;  
analysing AAM parameters for each face of the set of facial regions to provide an indication of facial expression; and

30 prior to said combining, removing faces having a defective expression from said set of facial regions.

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54. An apparatus according to claim 44, wherein said analysing said one or more sets comprises:

applying an Active Appearance Model (AAM) to each face of a set of facial regions;  
analysing AAM parameters for each face of the set of facial regions to provide an

5 indication of facial orientation; and

prior to said combining, removing faces having an undesirable orientation from said set of facial regions.

55. An apparatus according to claim 44 wherein said analysing one or more facial regions  
10 comprises:

applying an Active Appearance Model (AAM) to each facial region; and  
analysing AAM parameters for each facial region to provide an indication of facial  
expression.

15 56. An apparatus according to claim 44, wherein said analysing one or more facial regions comprises analysing at least one facial region to determine if an eye of said facial region is closed.

20 57. An apparatus according to claim 44, wherein said analysing one or more facial regions comprises analysing at least one facial region to determine if a mouth of said facial region is open.

25 58. An apparatus according to claim 44, wherein said analysing one or more facial regions comprises analysing at least one facial region to determine if a mouth of said facial region is frowning.

59. An apparatus according to claim 44 wherein the method further comprises displaying a corrected image based on said correcting and responsive to user interaction, adjusting the correcting of said corrected image.

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60. An apparatus according to claim 44, wherein said sequence of low resolution images is acquired for a time period not including a time for acquiring said main image.

61. An apparatus according to claim 44, wherein the method further comprises combining  
5 defect-free low resolution facial regions into a combined image, and correcting at least said  
portion of said defective main image facial region with image information from the combined  
image.

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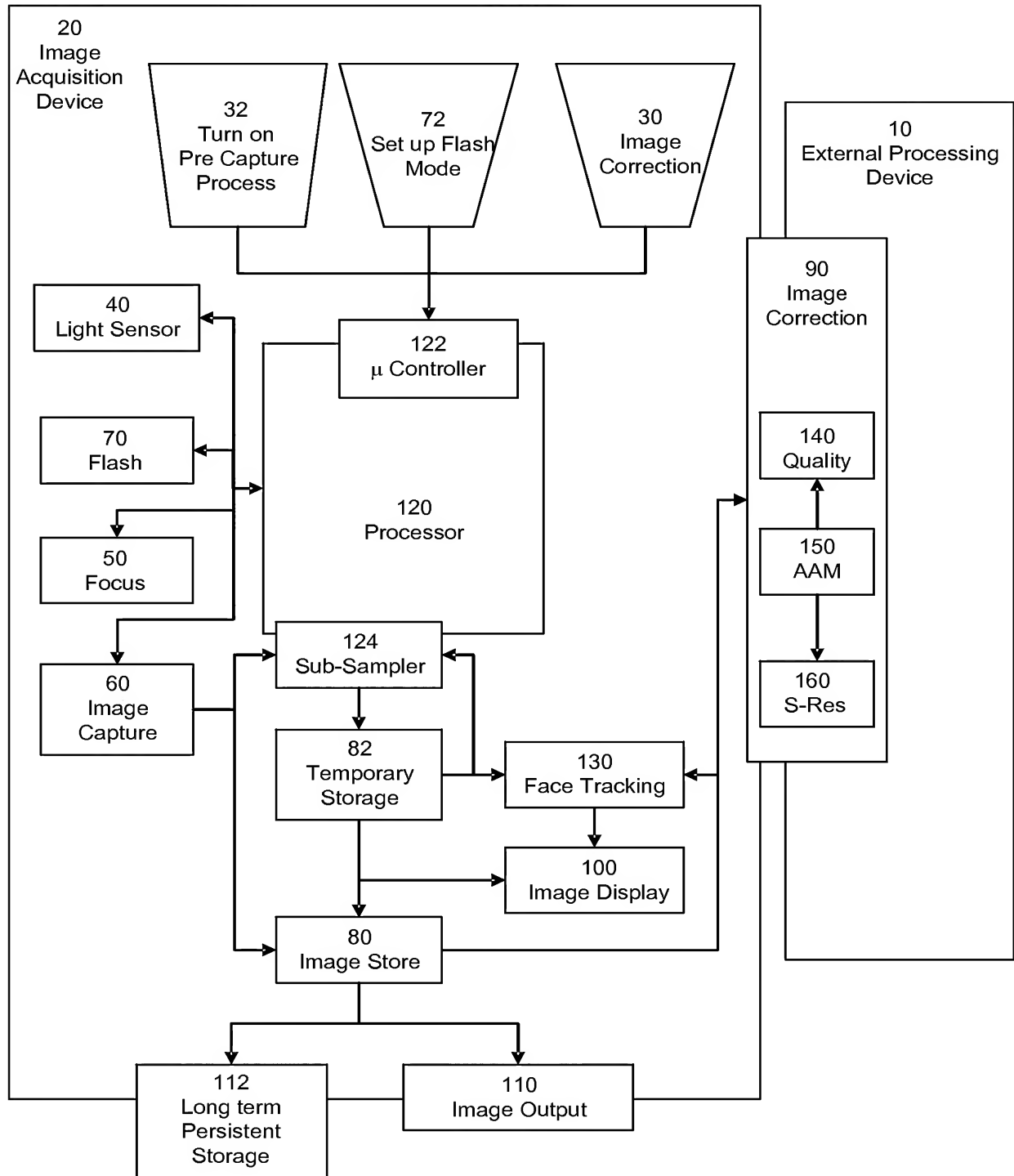


Figure 1

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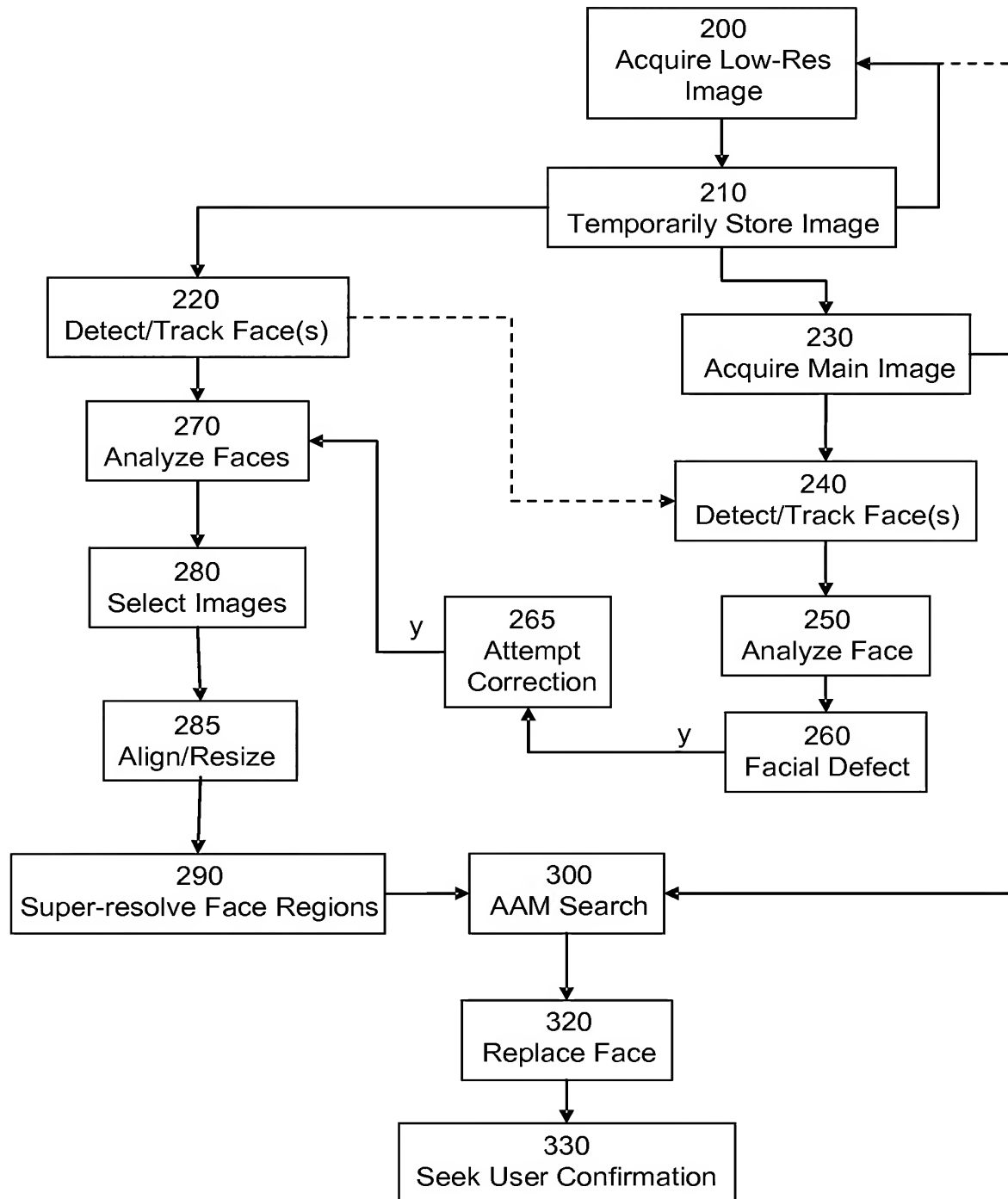
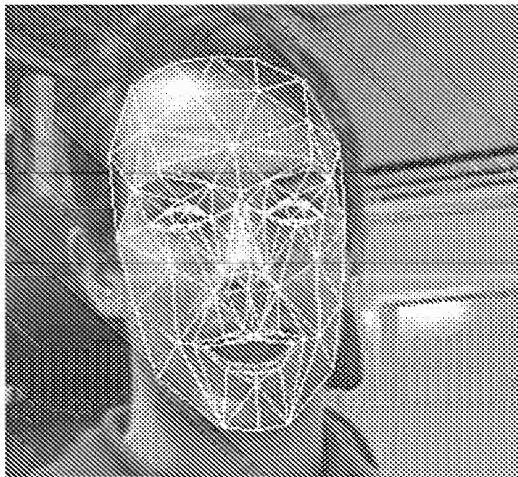
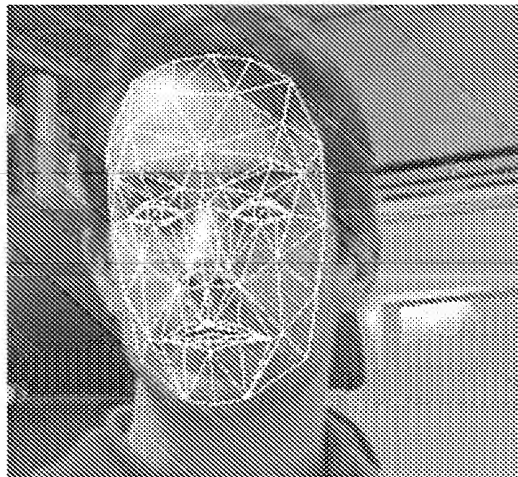


Figure 2

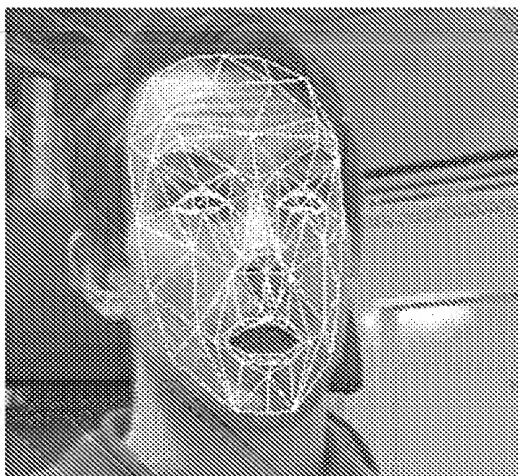
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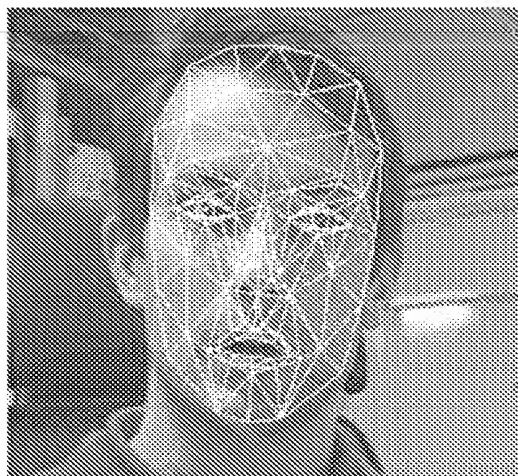
(a)



(b)



(c)



(d)

Figure 3

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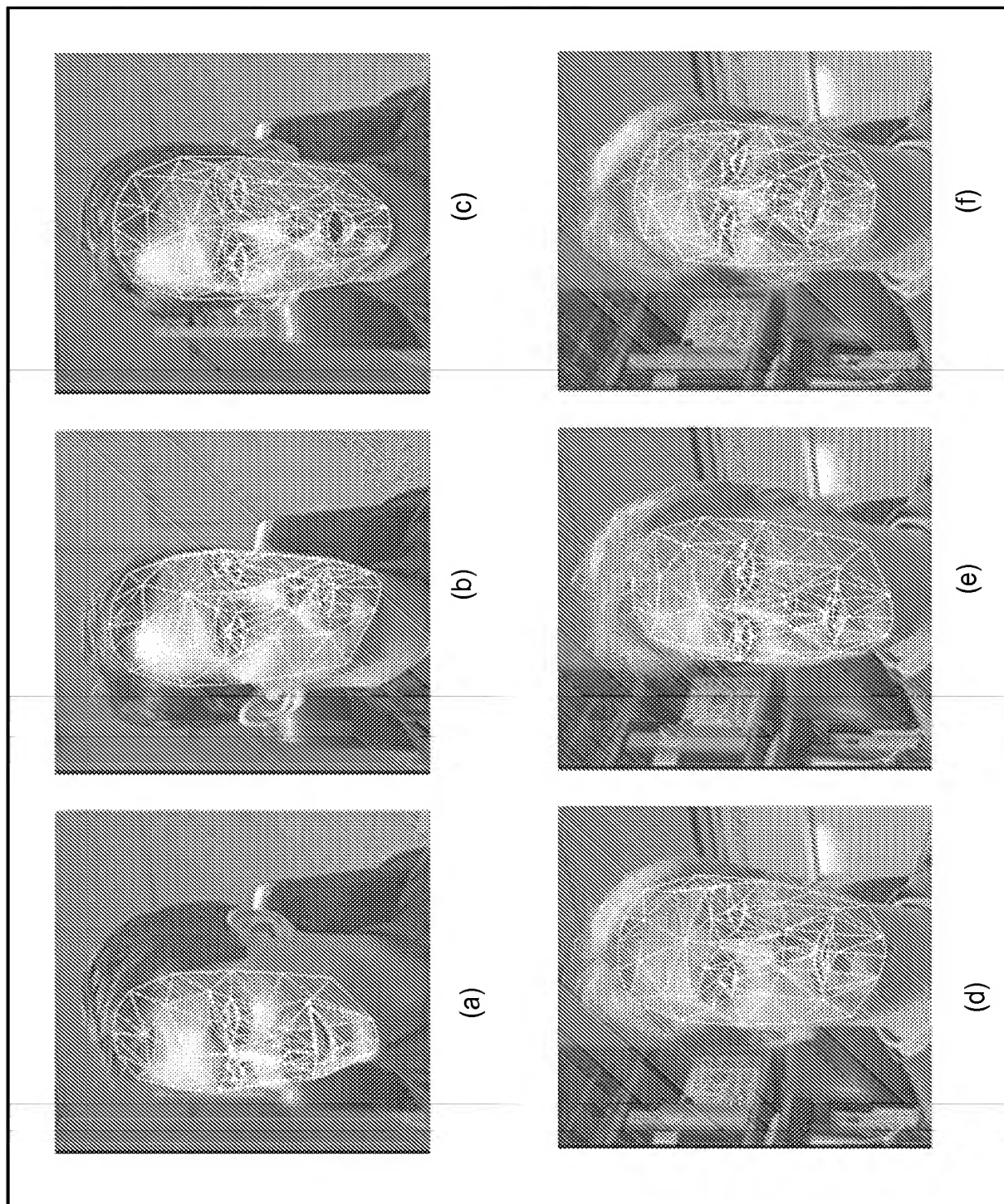


Figure 4

# INTERNATIONAL SEARCH REPORT

International application No.

PCT/US07/69593

<b>A. CLASSIFICATION OF SUBJECT MATTER</b> IPC: <b>G06K 9/00( 2006.01),9/36( 2006.01),9/32( 2006.01)</b>  USPC: <b>382/118,284,299</b> According to International Patent Classification (IPC) or to both national classification and IPC				
<b>B. FIELDS SEARCHED</b>  Minimum documentation searched (classification system followed by classification symbols) U.S. : 382/118, 284,299  Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched  Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)				
<b>C. DOCUMENTS CONSIDERED TO BE RELEVANT</b>				
Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.		
Y	US 20040223649 (Zacks et al) 11 November 2004 (11.11.2004), whole document	1-2,15- 21,23,24,31,32,36- 44,50,51,56-61		
Y	US 20070133901 (Aiso) 14 June 2007 (14.6.2007) paragraph 19	1-2,15- 21,23,24,31,32,36- 44,50,51,56-61		
<input type="checkbox"/> Further documents are listed in the continuation of Box C. <input type="checkbox"/> See patent family annex.				
<table style="width: 100%; border: none;"> <tr> <td style="width: 50%; vertical-align: top;">           * Special categories of cited documents:             "A" document defining the general state of the art which is not considered to be of particular relevance             "E" earlier application or patent published on or after the international filing date             "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)             "O" document referring to an oral disclosure, use, exhibition or other means             "P" document published prior to the international filing date but later than the priority date claimed         </td> <td style="width: 50%; vertical-align: top;">           "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention             "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone             "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art             "&amp;" document member of the same patent family         </td> </tr> </table>			* Special categories of cited documents:  "A" document defining the general state of the art which is not considered to be of particular relevance  "E" earlier application or patent published on or after the international filing date  "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)  "O" document referring to an oral disclosure, use, exhibition or other means  "P" document published prior to the international filing date but later than the priority date claimed	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention  "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone  "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art  "&" document member of the same patent family
* Special categories of cited documents:  "A" document defining the general state of the art which is not considered to be of particular relevance  "E" earlier application or patent published on or after the international filing date  "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)  "O" document referring to an oral disclosure, use, exhibition or other means  "P" document published prior to the international filing date but later than the priority date claimed	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention  "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone  "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art  "&" document member of the same patent family			
Date of the actual completion of the international search 09 July 2008 (09.07.2008)		Date of mailing of the international search report <b>16 SEP 2008</b>		
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US Commissioner for Patents P.O. Box 1450 Alexandria, Virginia 22313-1450 Facsimile No. (571) 273-3201		Authorized officer  Jingge Wu  Telephone No. (571)272-8535		